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SILVER-CADMIUM BATTERY DEVELOPMENT PROGRAM

QUARTERLY TECHNICAL PROGRESS REPORT

FOR (FIRST QUARTER), ENDING 20 NOVEMBER 1961

DATED

Andrew T. Biggs 6 Dec ~~1961~~ 1961 27p (Drefs)

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NASA
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Program Outline

A detailed program outline for the work in this program has been completed and is included in this report. The following discussion and description of work completed during this quarter as well as the work planned for the following quarter will be referenced to the outline in this and following reports.

PERSONNEL ASSIGNED TO THE PROGRAM

1. Power Sources Personnel:

A. T. Biggs - Senior Project Engineer, Program Manager
J. W. Rhyne, Jr. - Chief Electrochemist
J. L. Essex - Chief Mechanical Design Engineer
H. A. Jacobs - Design Engineer
T. W. O'Grady - Chief Test Engineer
J. J. Peloquin - Chemist
F. H. Barcomb - Chemical Laboratory Technician
V. M. Reiter - Test Laboratory Technician

2. Narmco Research and Development Division Personnel:

B. Levenetz - Program Manager
S. Yurenka - Engineering Research Manager
R. Elkin - Design Engineer
P. Sandoval - Fabrication Technician
V. Kindall - Chemist

3. Consultants

Dr. James H. Klein

Dr. A. Fleischer

Descriptions of the backgrounds of Doctors Klein and Fleischer are included in this report.

AUTOMATIC CYCLING EQUIPMENT

The specifications and a photograph of Power Sources' automatic charge-discharge cycling equipment are attached to this report.

PROGRAM OUTLINE
Silver Cadmium Development Program
Contract #NAS5-1431

- 1.0 Phase I - Container Design
The objective of this portion of the program is to develop and select the materials, design, and fabrication techniques for a filament-wound, resin-bonded, sealed, lightweight battery case.
- 1.1 Preliminary Design of Container
Various materials will be evaluated to determine their suitability for making a filament-wound battery case which will meet the requirements regarding internal pressure, impermeability, weight, and assembly process of the battery.
- 1.2 Selection of Resin System
Typical of the resin systems to be evaluated are the following:
- Polyamide - Bis-Phenol A type epoxy
- Polyamide - epoxy-novolak type epoxy
- Amine cured epoxy
- 1.3 Case Wall to Closure Seals
A study will be conducted to determine a method to assure a leak-tight seal between the cylinder wall and the end closure plate.
- 1.4 Ring Seal-to-Electrode Bonding
A study will be conducted to provide for positive bonding of the ring seals to the electrodes, properly positioning of the electrodes, and to provide a sealed cavity for the electrodes.
- 2.0 Phase II - Electrochemical Design
The objective of this portion of the program is to design and develop the electrochemical portion of the silver-cadmium battery and to integrate the design into the battery case design being developed under Paragraph 1.0.
- 2.1 Basic Battery Design
- 2.1.1 Duplex Plate Development
A study will be conducted to determine the best method of duplex plate construction.

2.1.1.1 Active Materials and Material Application

An investigation will be made into various active material formulations and application techniques which appear to be suitable for duplex plate fabrication.

2.1.1.1.1 Silver Peroxide

The following techniques and materials for the application of AgO active material to one side of silver foil base material are typical of those to be evaluated as to suitability to duplex plate construction:

A. Pasted Plate	AgO-Binder Paste
B. Sintered and Formed Plate	Ag ₂ O-Binder Paste
C. Sintered Un-formed Plate	Resin-Bonded Ag

2.1.1.1.2 Cadmium

Cadmium and cadmium-containing compounds or mixtures will be applied directly to one side of silver foil base material and the resulting plate structure will be evaluated as to suitability for duplex plate construction. The effect of conductive additives and expanders will be investigated. The following materials are typical of those to be evaluated:

A. Active Material

1. Cadmium hydroxide
2. Cadmium hydroxide with conductive additives
3. Cadmium hydroxide with conductive additive and expanders
4. Cadmium metal
5. Cadmium metal with conductive additives
6. Cadmium metal with conductive additives and expanders
7. Cadmium oxide
8. Cadmium oxide with conductive additives
9. Cadmium oxide with conductive additives and expanders

B. Conductive Additives

1. Silver metal
2. Silver oxide
3. Mercury
4. Mercuric oxide
5. Graphite

C. Expanders

1. Magnesium oxide
2. Thallium oxide
3. Indium oxide
4. Other suitable insoluble compounds.

2.1.1.2 Duplex Plate Fabrication Techniques

Duplex plates will be made utilizing various combinations of the more promising active material application techniques developed under Paragraph 2.1.1.1. The plates will be evaluated on the basis of ease of manufacture and mechanical properties.

2.1.1.3 Electrochemical Tests

Based on the results of Paragraph 2.1.1.2, duplex plates will be cycled in a multicavity test cell and the results evaluated on the basis of electrochemical efficiency, effect of depth of discharge effect of high charge and discharge rates, gas evolution, threshold potentials on both charge and discharge, gas evolution rates, electrolyte composition, etc.

2.1.1.3.1 Test Cell

A special test cell for the evaluation of duplex plate constructions and separator materials will be designed, fabricated and tested.

2.1.2 Separator Materials

The separator materials screened under the*ASD silver-cadmium battery development program will be evaluated as to suitability to the NASA duplex-plate battery configuration. Other separator materials will also be evaluated. The more promising of these materials will be tested in the special test cell developed under Paragraph 2.1.1.3.1.

2.1.3 Unit Cell Studies

Using the data obtained in the preceding studies, complete cells, utilizing to the maximum extent practicable the filament wound cell case construction and techniques developed in 1.0, will be designed, constructed and tested to determine various cell and plate operating characteristics such as: Voltage as a function of current density, allowable depth of discharge as a function of current density and cycle life, densification of the negative plate as a function of cycle life, gas pressure build up as a function of discharge and cycle life, etc.

* Contract No. AF 33(600) 42988

2.1.4

Multiple Cell Studies

In order to evaluate the combined operating characteristics of several cells, a number of identical cells will be constructed and placed in series on automatic cycle. The electrical performance will be monitored and periodically one cell of the group shall be removed, dis-assembled and an analysis of its internal condition made. Special note shall be made of the silver penetration of the separator layers, the amount of silver present in the negative plate, and the density of the negative material.

Different groups of cells shall be cycled under different charge and discharge currents, thus supplying data on the effect of varying current densities and depth of discharge.

2.2

Redox Systems

The redox systems screened under the ASD Silver-Cadmium Battery Development Program will be evaluated as to suitability to the NASA duplex-plate battery configuration. Any systems which appear promising will be tested first in the special test cell and subsequently in unit cells.

2.3

Silver Migration

2.3.1

Chelating Agents

The chelating agents screened under the ASD Silver-Cadmium Battery Development Program Contract No. AF 33(600)-42988 will be evaluated as to suitability to the NASA duplex-plate battery configuration. Any systems which appear promising will be tested first in the special test cell and subsequently in unit cells.

2.3.2

Ion Exchange Membranes

Ion exchange membranes will be studied as a means of providing a barrier which will prevent the migration of silver ions through the alkaline solution. Various commercially available ion-selective materials will be studied, and their ability to restrict migration shall be determined by analysis of silver ion concentration on both sides of the membrane after various periods of time.

3.0

Phase III - Prototype Fabrication and Testing

Starting in the sixth month of the program, the fabrication of a series of prototype batteries will be undertaken. These batteries will utilize the latest electrochemical design features and battery case fabrication techniques developed under Paragraphs 1 and 2 to that time.

The final detailed battery design and case configuration will be frozen by the end of the eleventh month. A minimum of eight complete prototype batteries shall be fabricated to this final design and tested according to Paragraph 3.2.

At the end of the test program, four prototype batteries will be delivered to NASA for their test and evaluation.

3.1 Test Program

3.1.1 Prototype Evaluation

Screening tests shall be conducted under accelerated test conditions by the use of higher loads and shorter cycle times. Groups of identical cell blocks shall be connected in series and the electrical performance and the internal pressure shall be monitored. Periodically, one cell block of the group shall be removed and disassembled and an analysis made of the internal condition of the cell block including the condition of the individual plates and separator materials. By this method, a progressive picture will be obtained of the change in the battery with increasing number of cycles.

A certain number of batteries shall be tested under normal service conditions and the performance of the batteries under these conditions correlated with the performance of the same batteries under accelerated conditions.

3.2 Eight prototype batteries made to the final design shall be put on test on or before the beginning of the thirteenth month of the program. These final tests shall run for a period of six months. Four of these batteries shall be tested under the specified loads and cycle times and four under accelerated conditions. The actual accelerated load and cycle time shall be selected on the basis of the correlation between previous normal and accelerated test results so as to represent the design goal conditions and still result in failure within the six-month period.

A final report summarizing the results of the various studies and tests and detailing the final design shall be submitted within one month after the completion of the test program.

REPORT

1.1 Preliminary Design of Container

1.2 Selection of a Resin System

During the selection of the case material, the stability of the plastic material in outer space environment was investigated. A literature survey has been made. Significant work in this area has been conducted by Norman E. Wahl of Cornell Aeronautical Laboratory. This report on "The Effects of High Vacuum and Ultraviolet Radiation on Plastic Materials", Contract AF 33(616)-6267, WADD T. R. 60-125, indicated that epoxy laminates would be satisfactory for space environments. Effect of vacuum in the order of 10^{-6} to 10^{-7} mm Hg. and ultraviolet flux ranging from 1/3 to 2-1/2 times the solar constant of 2 calories per cm^2 per min. were investigated. The equilibrium temperatures were dependant upon the intensity of the ultraviolet radiation and ranged between 250 to 465° F. It was found that the effect of U. V. Radiation is more severe than the effect of vacuum. The decrease in strength of the resin was not significant. It can be concluded, therefore, that the battery case which has a high strength safety factor and is probably within a vehicle which protects it from radiation, will not experience a significant degradation due to the space environment.

The preliminary inside diameter of the battery case was selected to be three inches. Two approaches have been used to establish the winding method and the integrity of the case.

A steel mandrel was designed and manufactured which permitted winding cases with one open and one closed end and served to establish the preliminary winding pattern and strength. An end plate and a test plug were designed and machined. The first and second cases were wound on this mandrel. The first case was wound with helical winding only on top of a teflon tape. In spite of a slightly tapered mandrel, the case was very difficult to remove from the mandrel.

The plug was bonded to the open end and the case pressurized with water. At 120 psig, the case started to leak around the

end plate joint and the test was interrupted. The winding pattern and integrity of the case were satisfactory.

The winding of the second case served for the study of silver lead sealing. The second case had a different winding pattern. There was one layer of circumferential windings in order to permit penetration by the silver ribbon. The ribbon was then bent on top of this layer and the winding was completed with a helical pattern. After curing, the case was sectioned and the area around the lead inspected. Microscopic investigations and peeling of layers revealed that the bond between silver and resin was inadequate. The reason for this was the contamination of the silver surface. It will be attempted to improve the bond by a different cleaning method of the silver; i.e., it is planned to wipe the grease off with MEK, clean for a few seconds with Nitric Acid, rinse and dry for 5 minutes at 1000°F.

The third case was wound on a different type of mandrel. This mandrel was slush molded from DMM (Desintegrating Mold Material) in a tubing and dried. Two end plates were wound in, using circumferential and improved helical winding patterns. One end plate had a steel pressure fitting. After curing, the mandrel was washed out. The case was pressurized with water and developed some leakage. The test was interrupted at 120 psi pressure.

These tests have shown that the attachment of the end plates is a critical area and requires some reinforcement. At the present time, Case No. 4 is being wound which includes several leads and modified end plate attachment. The weight of Case No. 3 (two end plates and the shell) was 0.25 pounds.

A preliminary drawing of the case assembly, Narmco RE 5266, was made and is being used for preliminary dimensioning of experimental components of the battery.

Glass fiber manufacturers do not supply fibers of smaller size than standard size one-end roving. Consequently, it was decided to use existing Owens-Corning Single-end fibers with "HTS" binder for developmental tests.

It was also decided to begin experiments with Epon 820 resin with a 10% addition of diethylenetriamine (DTA). This combination cures in 24 hours at room temperature. A portion of the filament wound wall of case No. 2 was cut out, weighed and soaked in a 40% solution of KOH. After 7 days, this portion was removed, washed, dried and weighed again. No visible changes were noted. A decrease in weight of 0.0002 gms from an original weight of 0.3063 gms was measured. This is a change of 0.065% which is considered negligible. After weighing, the specimen was returned to the solution of KOH, and will be checked every 7 days.

1.3

Case Wall to Closure Seals

Five glass flake laminates (6x6x0.25) were made and utilized as raw material for preliminary end plates. The resin used for this laminate was Union Carbide Polyepoxide P71. A small piece of one of the end plates was weighed and placed in a 40% solution of KOH. After 2 days, the end plate began to swell and became very soft and mushy. Another plate is being fabricated using Narmco-1174/3 resin. This plate will be soaked in 40% KOH, and changes will be observed. It is not anticipated that the resin of the end plates will present a problem. It is rather a selection of an available resin which has the chemical resistance to KOH and is adaptable to the molding process of the glass flake composite.

1.4

Ring Seal to Electrode Bonding

Evaluation of Various Elastomers

For the elastomeric seal to perform adequately, it must not be significantly deteriorated by continuous contact with 30% aqueous KOH solution (the electrolyte) held at 100°F. In other words, the rubber seal should not swell in the KOH solution or otherwise change dimensions, nor should it be attacked by the caustic solution and either change weight or decrease appreciably in strength.

It is also obvious that the rubber seal must be impermeable to the 30% aqueous KOH solution. In addition, the seal must be self-sealing to prevent electrolyte leakage after the injection of the KOH solution into the small cells by means of a hypodermic needle.

Eight types of elastomers have been tested. The materials have been compounded and molded into flat sheets about 0.080 x 6.0 x 6.0 inches. From these molded sheets, half-inch wide "dog bone" tensile strength test specimens were cut.

The initial tensile strength and elongation values of these eight type elastomers were obtained. Tensile strength and elongation values were then determined after 7 days soaking in 30% KOH solution maintained at a temperature of 100°F. Thirty-day soak results have also been obtained on the first four materials. The eight elastomers being screened are characterized as follows:

- Enjay 035, a butyl rubber
- Hycar 1042, a nitrile rubber
- Cis-4, a polybutadiene rubber (two formulations)
- Shell's S-1509, a styrene-butadiene rubber
- Hycar 2001, a high styrene butadiene rubber
- Shell's 305WP, a polyisoprene rubber
- DuPont's Adiprene C, a urethane elastomer

The last four were selected because of their known favorable resistance to highly alkaline conditions and to H₂O. Results of these tests are shown in Table I.

Because of the very high elongation of Shell's 305WP, Adiprene C, and the Cis-4 elastomers, some difficulty was experienced in obtaining reliable elongation values with the testing equipment available. In many instances the gage length was shortened to .25" to 1" instead of the standard 2". This procedure gave reasonable tensile strength values, but the per cent elongation was increased significantly as the gage length was reduced. With the same composition, for example, the per cent elongation would nearly double as the gage length was reduced to 1" from the standard 2".

Having to change the gage length made it difficult to determine the true effect of the KOH soak on the elongation of the elastomeric composition.

To observe dimensional and weight changes, the thickness, width, and weight of the "dog bone" were determined initially

and after 7 and 30 days soaking in 30% KOH solution held at 100°F. The results obtained are shown in Tables II, III, and IV.

Any changes in the physical properties of these elastomeric compositions will also be determined after longer periods of soaking in 30% KOH solution at 100°F.

Bonding of Silver Foil to Itself

Studies have been conducted in order to learn of any problems associated with the silver in obtaining good bonds to the elastomer. Metlbond 3135 adhesive was used to prepare 1/8" overlap bonds with 0.5" x 0.002" x 1.5" strips of silver foil at a pressure of 5 psi. Initial room temperature tensile strengths were obtained and again after 7 days soaking in aqueous 30% KOH solution at 100°F.

Four different preparative conditions were studied:

- (1) Degreased bonding surface-elastomer cured at room temperature.
- (2) Degreased bonding surface-elastomer cured at 135-140°F.
- (3) Light sanding of bonding surface-elastomer cured at room temperature.
- (4) Light sanding of bonding surface-elastomer cured at 135-140°F.

The 1/8" overlap bonds, prepared under all four conditions and tested in tension at room temperature, were stronger than the metal foil. The metal failed at a load of about 40 pounds, which was close to that calculated for the tensile strength of the 2 mil silver foil used. The stress level in the adhesive joint exceeded 640 psi. Two or three test specimens were tested under each bonding condition.

After 7 days soak in 100°F 30% KOH solution, the bonds prepared under conditions (1), (2), and (4), above were still stronger than the metal. However, those specimens prepared under condition (3) failed at an average tensile strength of 350 psi - about 1/2 the load needed to break the silver foil.

Bonding of Hycar 1042 to Silver Foil

Test specimens were prepared by bonding 0.15" x 0.125" x 0.080" pieces of compounded Hycar 1042 to 2 pieces of 0.5" x 0.002" x 1.5" silver foil at a pressure of 5 psi. The foil overlapped the rubber with one piece on one side and one on the other. Metlbond 3135 was again used as the adhesive. The cure consisted of 24 hours at room temperature and 2 hours at 135-140°F. These specimens were tested in tensile shear at room temperature. Adhesion failure occurred in each case between the metal and the rubber at an average stress of 300 psi. It is believed that this strength would be adequate in the battery application.

After 7 days soaking in 30% KOH solution at 100°F, an average tensile strength of 179 psi was obtained. The specimens, as before, failed in adhesion. Although this stress level is less than the 300 psi obtained prior to soaking, there is no evidence to show that the Metlbond 3135 was significantly degraded by the KOH solution.

Bonding of Unrinsed, Blotted, KOH Soaked Hycar to Silver Foil

Bonds were prepared in the same manner as above. In this case, however, the Hycar 1042 was soaked in 40% KOH solution overnight. The pieces of Hycar 1042 were blotted until the surface was dry prior to bonding.

These bonds failed in adhesion at an average stress level of 58 psi compared with 300 psi for the unsoaked rubber.

Bonding of Cellophane-Membrane

As a means of facilitating assembly of the Silver-Cadmium battery, Metlbond 3135 was used to bond the edges of 6 circular pieces of Pudo 300 cellophane. Good bonding resulted but better techniques should be developed to prevent excessive flow of the adhesive into the interior of the cellophane layers.

2.1.1

Duplex Plate Development

The following paragraphs (2.1.1.1.1, 2.1.1.1.2, and 2.1.1.3) describe the activities to date in the area of Duplex Plate Development.

2.1.1.1.1

Silver Peroxide

The pasting method of application using a paste mixture composed of chemically prepared silver-peroxide and carboxy-methyl-cellulose (CMC) binder has proven impractical for duplex electrode construction, the reason being that the paste mixture is un-controllable. The paste mixture has too great a tendency to run under the mask which is used as a pasting fixture. This method of construction has been temporarily dropped from the program, pending further studies into techniques of masking. The first test cell made under this program was constructed using this method. The results of the cell are described under paragraph 2.1.1.3, Electrochemical Tests.

An alternate technique which has shown greater promise employs the use of the chemically prepared silver-peroxide applied to the grid in a powder form within the pasting mask. After the material is uniformly spread over the active area a few drops of 2% polyvinyl alcohol (PVA) binder are placed in the dry powder and allowed to soak in, binding the material. This method was employed for the second test cell made under this program. The results of the cell are described under paragraph 2.1.3, Electrochemical Tests.

The use of a sintered and formed plaque employing monovalent silver-oxide and binder has proven unsuccessful because of the amount of masking required in the forming operation, to prevent the conversion of the electrode to silver-oxide and has been dropped from the program.

The sintered, resin-bonded technique of active material application has proven the most successful. In this technique, a sheet of resin-bonded silver powder of appropriate diameter and thickness is placed in the duplex electrode and heat-bonded in place. The electrode is then placed in a sintering furnace. During the process of sintering, the resin used for bonding the silver particles together is burned out of the material.

The electrode prepared in this manner is assembled in the cell in the discharged state. That is, the electrode is not formed to the oxide state until after cell assembly and the addition of electrolyte. This method was employed for the third test cell made under this program. The results of the cell are described under paragraph 2.1.1.3, Electrochemical Tests.

2.1.1.1.2

Cadmium

The same problems encountered in the silver peroxide studies (2.1.1.1.1) were encountered in the cadmium study. The carboxy-methyl-cellulose (CMC) binder has been found unsuitable for use in the duplex electrode construction. The use of CMC binder has also been temporarily dropped from the cadmium electrode studies.

The alternate technique as used in the silver-peroxide studies has shown the greatest promise in the cadmium studies. This technique involves the application of dry cadmium powder or cadmium-hydroxide powder with appropriate additives, uniformly spreading the powder, and finally adding the Polyvinyl alcohol (PVA) binder.

The resin-bonded technique as used in the silver-peroxide studies is not applicable to the cadmium electrode studies.

2.1.1.3

Electrochemical Tests

Three 3 plate test cells have been constructed as follows:

Cell A. Positive Electrode - AgO - 2% CMC binder.

Negative Electrode - Cadmium Powder - 5% Ag₂O
2% CMC binder.

Separators - 1 layer EM-341 (Kendall Mills) adjacent to each electrode surface, and 6 layers 300 PUD-O Cellophane (DuPont) between layers of EM-341.

Electrolyte - 40% KOH.

Cell B. Positive Electrode - Ag + 5% Ag powder - 2% PVA binder.

Negative Electrode - Cadmium Powder - 5% Ag₂O
2% PVA binder.

Cell C. Positive Electrode - Resin-Bonded - Sintered Ag.

Negative Electrode - $\text{Cd}(\text{OH})_2$ + 5% Ag - PVA binder.
Separators and Electrolyte - same as used in Cell A.
with the exception that 4 layers cellophane were used
rather than 6 layers.

Test Results

Cell A exhibited several electrolyte leakage paths apparently between gaskets and electrodes before any charge-discharge cycles. The cell was dis-assembled for examination and subsequently scrapped. It was determined that the non-lubricated surface of the gasket-electrode interface and gasket-cell case interface did not provide an adequate seal against electrolyte. Subsequent cells will be assembled using KEL-F wax as a gasket lubricant to prevent electrolyte leakage.

Cell B exhibited a high internal resistance upon all attempts of discharging or charging and consequently very poor voltage response. The poor performance of the cell was attributed to a deficiency of electrolyte. The cell was disassembled and electrolyte was added to it. Further attempts at discharging yielded very marginal performance. The cell was again dis-assembled and a critical analysis was made of all components. The conclusion drawn was that the space between the electrodes was too great. The cell was scrapped after the analysis.

The third cell, Cell C, was assembled with special attention paid to the sizing of all components in order to optimize the electrode spacing, but at the time of this report no electrical tests have been conducted. A photograph of the completed test cell is attached to this report.

2.1.2

Separator Materials

No conclusions have yet been drawn from the ASD Battery Development Program.

2.1.1.3.1

Test Cell

A test cell fixture has been designed and tested. The fixture is composed of .5 inch thick methyl-methacrylate (Plexiglass) plates, 6 inches square. Circular bolt hole patterns are drilled in each plate for clamping the cell together. This fixture allows a large gasket sealing area while maintaining appropriate diameters for the electrodes and separators. The

fixture was assembled, using gaskets similar to the ring seals to be used in the ultimate battery design and was pressure tested at 150 psig to verify its ability to prevent leakage when cells are assembled and tested. Six sets of fixtures have been ordered, and are on hand for preliminary cell testing.

TABLE I
CHANGES OF MATERIAL PROPERTIES

Type Elastomer	Before Soaking		After 7 Days Soaking*			After 30 Days Soaking*		
	Tensile Strength psi	Elongation %	Tensile Strength psi	Elongation %	% Change in Original Tensile Strength	Tensile Strength psi	Elongation %	% Change in Original Tensile Strength
Enjay 035	774	375	713	258	-7.9	807	275	+4.27
Hycar 1042	1346	144	1178	143	-12.5	1386	250	+2.97
Cis-4								
Formulation A	575	715	449	325	-21.9	415	716	-27.8
Cis-4								
Formulation B	591**	1113	-	-	-	554	1239	-6.25
Shell's S-1509	753	314	741	609	-1.59	-	-	-
Hycar 2001	1559	246	1328	367	-14.8	-	-	-
Adiprene C	951	814	1033	1900***	+8.6	-	-	-
Shell's 305WF	1153	634	1432	1693***	+24.2	-	-	-

* At 100°F in 30% KOH solution.

** Approximate, (3 of the specimens had too much elongation to break within the limits of the Instron testing machine).

*** To break these elastomers a very short gauge length was used, thus making these elongation values meaningless.

TABLE II
CHANGES OF DIMENSIONS AND WEIGHT

Type Elastomer	Before Soaking			After 7 Days Soaking*		
	Thickness	Width	Weight	Thickness	Width	Weight
<u>Enjay 035</u> Specimen No.						
1	0.088	0.511	6.6563	0.088	0.512	6.6720
2	0.084	0.513	6.4654	0.085	0.511	6.4715
3	0.077	0.514	-	0.078	0.513	-
4	0.084	0.514	-	0.084	0.513	-
<u>Hycar 1042</u> Specimen No.						
A	0.079	0.515	6.7807	0.079	0.514	6.7795
B	0.079	0.510	6.7780	0.079	0.509	6.7767
C	0.079	0.513	-	0.079	0.510	-
D	0.079	0.513	-	0.079	0.509	-
E	0.080	0.512	-	0.080	0.509	-
<u>Cis-4</u> <u>Formulation A</u> Specimen No.						
1A	0.081	0.516	6.0323	0.081	0.515	6.0307
2A	0.083	0.512	6.1176	0.083	0.512	6.1206
3A	0.083	0.516	-	0.083	0.514	-
4A	0.082	0.516	-	0.080	0.515	-
<u>Cis-4</u> <u>Formulation B</u> Specimen No.						
1B	0.083	0.517	6.2577	0.084	0.517	6.2594
2B	0.085	0.515	6.3590	0.084	0.516	6.3603
3B	0.086	0.515	-	0.085	0.516	-
4B	0.088	0.517	-	0.086	0.515	-

* At 100°F in 30% KOH solution

TABLE III
CHANGES OF DIMENSIONS AND WEIGHT

Type, Elastomer	Before Soaking			After 30 Days Soaking*		
	Thickness Inches	Width Inches	Weight Grams	Thickness Inches	Width Inches	Weight Grams
Enjay 035 Spec. No.						
5	0.077	0.513	5.7263	0.078	0.513	5.7576
6	0.077	0.511	5.7251	0.078	0.513	5.7695
7	0.078	0.512	-	0.079	0.514	-
8	0.083	0.514	-	0.083	0.512	-
Hycar 1042 Spec. No.						
F	0.079	0.511	6.7787	0.078	0.510	6.7772
G	0.079	0.512	6.6872	0.078	-	6.6859
H	0.078	0.511	-	0.078	-	-
I	0.080	0.511	-	0.080	-	-
J	0.078	0.511	-	0.078	-	-
Cis-4 Formulation A Spec. No.						
5A	0.083	0.518	6.0193	0.082	0.518	6.0272
6A	0.085	0.520	6.0530	0.082	0.516	6.0637
7A	0.079	0.510	-	0.079	0.515	-
8A	0.082	0.511	-	0.081	0.516	-
Cis-4 Formulation B Spec. No.						
5B	0.086	0.516	6.3725	0.083	0.503	6.3906
6B	0.085	0.503	6.1059	0.082	0.505	6.1190
7B	0.087	0.505	-	0.085	0.513	-
8B	0.085	0.512	-	0.081	0.513	-

* At 100°F in 30% KOH solution

TABLE IV
CHANGES OF DIMENSIONS AND WEIGHT

Type Elastomer	Before Soaking			After 7 Days Soaking*		
	Thickness Inches	Width Inches	Weight Grams	Thickness Inches	Width Inches	Weight Grams
Shell's S-1509 Spec. No.						
1C	0.083	0.515	6.2517	0.083	0.514	6.2455
2C	0.082	0.518	6.1613	0.082	0.516	6.1530
3C	0.085	0.515	-	0.085	0.516	-
4C	0.082	0.517	-	0.082	0.517	-
Hycar 2001 Spec. No.						
1D	0.078	0.515	6.2982	0.078	0.514	6.2944
2D	0.078	0.515	6.3990	0.079	0.514	6.3954
3D	0.078	0.515	-	0.078	0.512	-
4D	0.084	0.514	-	0.084	0.512	-
Adirpene C Spec. No.						
1E	0.080	0.514	6.2450	0.080	0.515	6.1868
2E	0.080	0.512	6.2435	0.081	0.515	6.1850
3E	0.078	0.513	-	0.079	0.512	-
4E	0.079	0.515	-	0.079	0.511	-
Shell's 305WP Spec. No.						
1F	0.086	0.515	6.3264	0.086	0.515	6.3242
2F	0.084	0.514	6.3083	0.085	0.515	6.3050
3F	0.085	0.515	-	0.086	0.518	-
4F	0.085	0.515	-	0.086	0.517	-

* At 100°F in 30% KOH solution.

ARTHUR FLEISCHER - Consultant

Education

Graduate of Sheffield Scientific School with a Bachelor of Science degree in Chemistry, Summa Cum Laude.

Graduate School at Yale University with a Doctor of Philosophy degree in Physical Chemistry.

**Present
Company
Affiliation**

Consultant to Power Sources Division of Telecomputing Corporation in the fields of energy storage and conversion systems employing silver as the positive electrode and cadmium or zinc as the negative electrode.

**Previous
Job
Affiliation**

Senior Scientist in Electrochemistry at Thomas A. Edison Research Laboratory, Division of McGraw-Edison Co., West Orange, New Jersey, with major activities on vented and sealed nickel-cadmium batteries and fuel cells.

Research Director at Nicad Division, Gould-National Batteries, Inc., in charge of research and development of sintered-plate nickel-cadmium batteries.

JAMES H. KLEIN - Consultant

Education	Graduate of Massachusetts Institute of Technology with B. S. and M.S. degrees in Mechanical Engineering and D.Sc. degree in Chemical Engineering. Twelve years experience in the development of new ideas and inventions and in the organization of companies to commercially exploit these developments. Listed in American Men of Science. Registered Professional Engineer in California and Colorado.
Present Work	Consulting Engineer - Power Sources, development of energy storage and conversion systems; Ball Brothers Research Corp., satellite instrumentation; University of Colorado Medical School, design of medical research experiments and equipment; on Board of Directors of following companies: Frost Engineering Development Corp, development and manufacture of electromechanical components; Uptime Corp., development and manufacture of high speed card readers for digital computers; Umbroiler Co., solar energy devices; Motion, Inc., development and manufacture of advertising devices.
Previous Job Affiliations	<p>Director of Engineering, Stanley Aviation Corp., Denver, Colorado. Responsible for all engineering design and development.</p> <p>Member Technical Staff, Ramo Woodridge Corp., Denver, Colorado. Technical responsibility for sale and subsequent development programs on instrumentation systems for nuclear power plants. ---Los Angeles, California. Technical direction and coordination of designs and construction of all test facilities for the Titan ICBM development program.</p> <p>Consulting Engineer, Boston, Massachusetts. Development and commercial application of new inventions including tool steels, process instrumentation, geophysical exploration, utilization of solar energy.</p> <p>Technical Director, New Invention Division of Southwest Research Institute, San Antonio, Texas. Responsible for development and subsequent commercialization of all new invention activities.</p> <p>Project Engineer, American Research and Development Corporation, Boston, Massachusetts. Responsible for long range development program on mass-algae culture.</p>

SPECIFICATION FOR AUTOMATIC BATTERY CYCLING CHARGING AND DISCHARGING UNIT.

Model Number RAC-250-6CC-25CP(50)CYC.

Manufactured by Republic Aircraft Co.

This unit consists of the following, and operates from nominal 115/230V \pm 10% 1 phase, 60 cycle, AC power.

A. (2) CC units, 0.1-6A, 0-50 VDC Regulation: Approx. 1% from 0-50 V with CC discharge incorporated in above units, as automatically switched by appropriate timers. All separately adjustable.

B. (2) CP units 0-25 Amp., Cont. and 0-32 Amp. max. Intermitently 0-50 V. Regulation: Approx. 1% over 5-50 VDC. Current-limiting at specified level - adjustable over reasonable range (5-10-25A).

(2) CC discharge units with timers to work in conjunction with CP units.

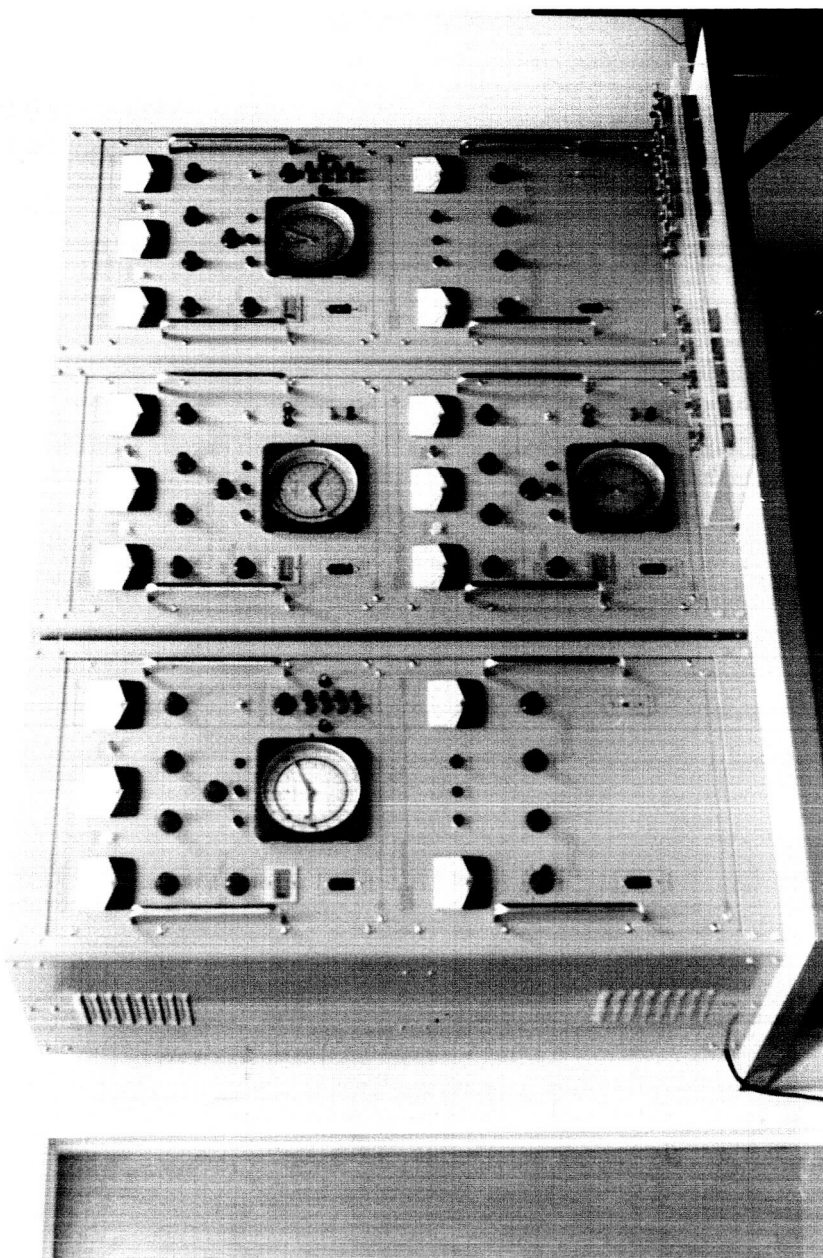
Automatic switch-overs and parallel CP charge-series CC discharge switch covers, automatic.

C. Power Failure system stops units, continues at previously stopped positions with manual reset.

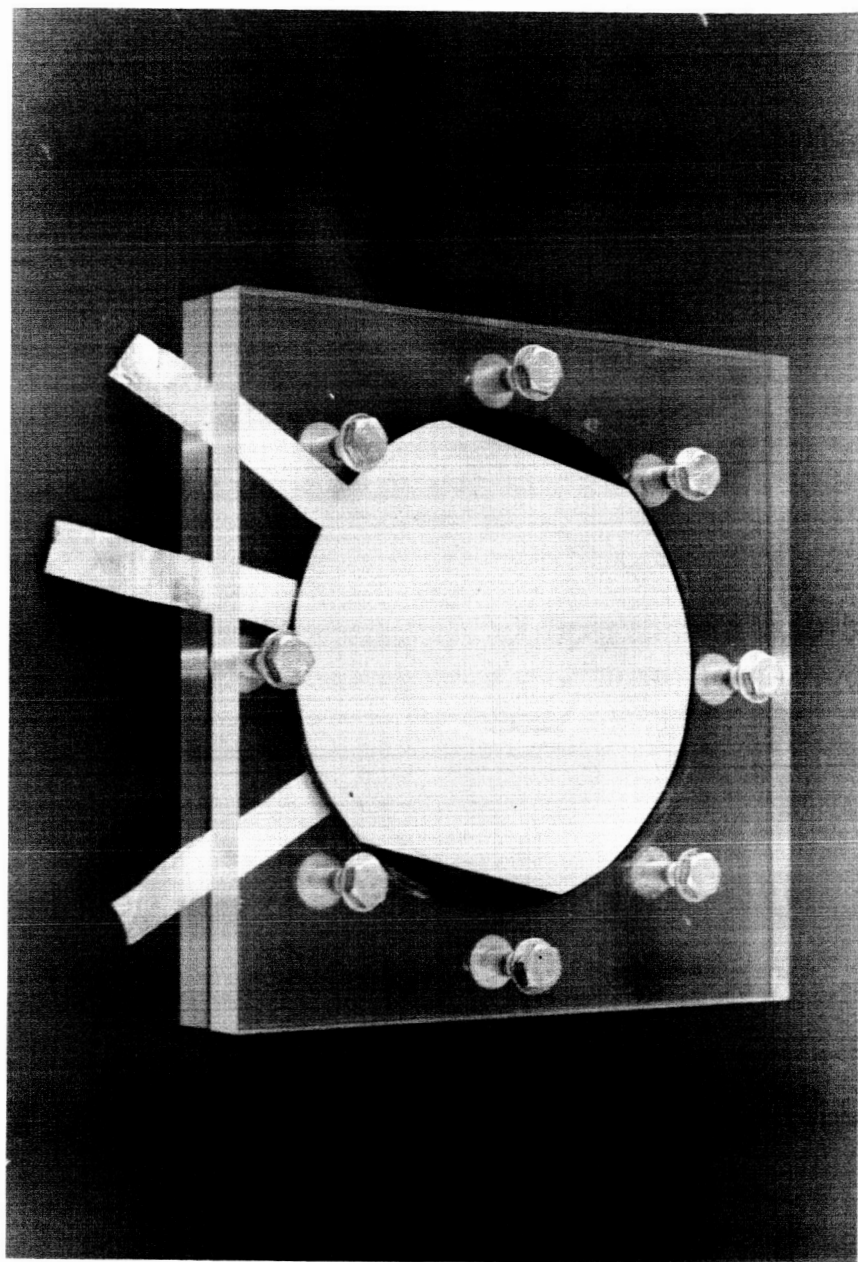
D. Clock on input side and form cycle counters. Two AC receptacles on output side of input breaker.

E. All charge and discharge functions have appropriate metering, either zero-centered or standard.

F. Dimensions - Approximately 6' x 22-1/4 x 18D.



AUTOMATIC CYCLING EQUIPMENT



EXPERIMENTAL CELL